



## Herbicide How-to: Understanding Herbicide Mode of Action

Joe Armstrong  
Extension Weeds Specialist

The large number of herbicide options—new products, old products with new names, new formulations of old products, premixes, and generics—can make weed control a difficult and confusing task. In addition to knowing the crops in which a herbicide can be used, the weeds it will control, the appropriate rate, and any necessary adjuvants to include, it is also important to know and understand the herbicide's mode of action to design a successful weed management program.

### What is “Mode of Action?”

The mode of action is the way in which the herbicide controls susceptible plants. It usually describes the biological process or enzyme in the plant that the herbicide interrupts, affecting normal plant growth and development. In other cases, the mode of action may be a general description of the injury symptoms seen on susceptible plants. In Oklahoma crop production, 11 different herbicide modes of action are commonly used, and each is unique in the way it controls susceptible plants. Some herbicide modes of action comprise several chemical families that vary slightly in their chemical composition, but control susceptible plants in the same way and cause similar injury symptoms.

Herbicides can also be classified by their “site of action,” or the specific biochemical site that is affected by the herbicide. The site of action is a more precise description of the herbicide's activity; however, the terms “site of action” and “mode of action” are often used interchangeably to describe different groups of herbicides.

### Why is it Important to Know the Mode of Action?

Knowing and understanding each herbicide's mode of action is an important step in selecting the proper herbicide for each crop, diagnosing herbicide injury, and designing a successful weed management program for your production system. Over-reliance on a single herbicide active ingredient or mode of action places heavy selection pressure on a weed population and may eventually select for resistant individuals. Over time, the resistant individuals will multiply and become the dominant weeds in the field, resulting in herbicides that are no longer effective for weed control. Simply rotating herbicide active ingredients is not enough to prevent the development of herbicide-resistant weeds. Rotating herbicide modes of action, along with other weed control methods, is necessary to prevent or delay herbicide-resistant weeds. Always read each product's label to determine the mode of action and best management practices for herbicide-resistant weeds.

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Many weeds have developed “cross resistance” and are resistant to multiple herbicides within a single mode of action. Most waterhemp populations in Oklahoma, for example, are cross-resistant to both Scepter (chemical family: imidazolinone) and Classic (chemical family: sulfonyleurea). Both of these herbicides are ALS inhibitors, but belong to different chemical families within the same mode of action. Therefore, it is important to not only rotate herbicide active ingredients but also to rotate modes of action to prevent herbicide-resistance weed populations from developing. One of the most effective ways to rotate herbicide modes of action is through crop rotation.

Weeds that have developed “multiple resistance” are resistant to herbicides from two or more modes of action. At this time, there are no weeds in Oklahoma that have been confirmed as resistant to multiple herbicide modes of action; however, instances of weeds with multiple resistance can be found in neighboring states. ALS-resistant, PPO-resistant, and glyphosate-resistant populations of waterhemp have been confirmed in Kansas. As well, Italian ryegrass populations in Arkansas have been confirmed to be resistant to both ALS- and ACCase inhibitor herbicides.

### How can I Determine the Herbicide's Mode of Action?

Information regarding each product's mode of action can sometimes be found on the front of the herbicide label. Often, the herbicide is described as being a member of a particular numbered group. These numbers refer to a specific mode of action and were developed to consistently organize herbicides based on their mode of action. For example, “Group 1” herbicides are ACCase inhibitors and “Group 2” herbicides are ALS inhibitors. Some herbicides will list the mode of action somewhere in the general instructions or product description in the label. In other situations, products may not mention the mode of action anywhere in the label. If you are unsure of the herbicide's mode of action, contact your local county extension educator for clarification.

### What are the Different Modes of Action? What are their Characteristics?

The following is a short description of the 11 most commonly used herbicide modes of action in Oklahoma crop

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**ACCase Inhibitors**

<i>Group</i>	<i>Chemical family</i>	<i>Trade names</i>	<i>Active ingredient</i>
1	Arloxyphenoxypropionate "FOPs"	Assure II Hoelon' Fusilade Puma	quizalofop diclofop fluazifop fenoxaprop
1	Cyclohexanedione "DIMs"	Select, Select Max, others Poast, Poast Plus	clethodim sethoxydim
1	Phenylpyrazoline "DENS"	Axial XL	pinoxaden

**ALS Inhibitors**

<i>Group</i>	<i>Chemical family</i>	<i>Trade names</i>	<i>Active ingredient</i>
2	Imidazolinone "IMIs"	Beyond, Raptor Cadre Pursuit Scepter	imazamox imazapic imazethapyr imazaquin
2	Sulfonylurea "SUs"	Accent Ally Amber Autumn Beacon Classic Express Glean Harmony Maverick Option Osprey Peak Permit Resolve	nicosulfuron metsulfuron triasulfuron iodosulfuron primisulfuron chloriumuron tribenuron chlorsulfuron thifensulfuron sulfosulfuron foramsulfuron mesosulfuron prosulfuron halosulfuron rimsulfuron
2	Triazolopyrimidine	FirstRate PowerFlex Python Strongarm	cloransulam-methyl pyroxsulam flumetsulam diclosulam
2	Pyrimidinyl(thio)benzoate	Staple	pyrithiobac
2	Sulfonylaminocarbonyltriazolinones	Everest Olympus	flucarbazone propoxycarbazone

**Root Growth Inhibitors**

<i>Group</i>	<i>Chemical family</i>	<i>Trade names</i>	<i>Active ingredient</i>
3	Dinitroaniline	Treflan, others Prowl, others Sonalan	trifluralin pendimethalin ethafluralin

**Growth Regulators**

<i>Group</i>	<i>Chemical family</i>	<i>Trade names</i>	<i>Active ingredient</i>
4	Phenoxy-carboxylic acid	many Butyrac, others	2,4-D 2,4-DB MCPA
4	Benzoic acid	Banvel, Clarity, Status, others	dicamba
4	Pyridine carboxylic acid	Stinger Starane Tordon', Grazon'	clopyralid fluroxypyr picloram
4	Quinoline carboxylic acid	Paramount	quinclorac

## Photosynthesis Inhibitors (Photosystem II)

Group	Chemical family	Trade names	Active ingredient
5	Triazine	Aatrex <sup>r</sup> , atrazine <sup>r</sup> , others Princep Caparol	atrazine simazine prometryn
5	Triazinone	Sencor Velpar	metribuzin hexazinone
5	Uracil	Sinbar	terbacil
6	Nitrile	Buctril, others	bromoxynil
6	Benzothiadiazinone	Basagran	bentazon
7	Urea	Linex, Lorox Karmex	linuron diuron

## Shoot Growth Inhibitors

Group	Chemical family	Trade names	Active ingredient
8	Lipid synthesis inhibitor, thiocarbamate	Eptam	EPTC
15	Chloroacetamide	Dual, Cinch, others Intrro <sup>r</sup> , Micro-Tech <sup>r</sup> Harness <sup>r</sup> , Degree <sup>r</sup> , Surpass <sup>r</sup> , others Outlook	metolachlor alachlor acetochlor dimethenamid-P
15	Oxyacetamide	Define	flufenacet

## Aromatic Amino Acid Synthesis Inhibitors

Group	Chemical family	Trade names	Active ingredient
9	Glycine	Roundup, Touchdown, others	glyphosate

## Glutamine Synthesis Inhibitors

Group	Chemical family	Trade names	Active ingredient
10	Phosphonic acid	Ignite, Liberty	glufosinate

## Pigment Synthesis Inhibitors

Group	Chemical family	Trade names	Active ingredient
12	Pyridazinone	Zorial Rapid 80	norflurazon
13	Isoxazolidinone	Command	clomazone
27	Triketone	Callisto Laudis Impact	mesotrione tembotrione topramezone
27	Isoxazole	Balance <sup>r</sup>	isoxaflutole

## PPO Inhibitors

Group	Chemical family	Trade names	Active ingredient
14	Diphenylether	Blazer Reflex, Flexstar Cobra Goal	acifluorfen fomesafen lactofen oxyfluorfen
14	N-phenylphthalimide	Valor Resource	flumioxazin flumiclorac
14	Thiadiazole	Cadet	fluthiacet
14	Triazolinone	Aim Spartan, Authority	carfentrazone sulfentrazone

## Photosynthesis Inhibitors (Photosystem I)

Group	Chemical family	Trade names	Active ingredient
22	Bipyridilium	Gramoxone Inteon <sup>r</sup> , others Reglone, others	paraquat diquat

<sup>r</sup> Restricted use pesticide.

production. The list of herbicides in the accompanying table (found on the inside pages) is not exhaustive and does not account for herbicide premixes that contain two or more active ingredients. If you have questions regarding mode of action, consult the individual product label and support literature from the manufacturer or contact your county agricultural Extension educator for more information.

### **ACCase Inhibitors (Group 1)**

Inhibitors of the ACCase enzyme in plants are used strictly for grass control. As a result, they are used primarily in broadleaf crops or fallow situations, but there are also some products labeled for use in grass crops to control specific grass weeds. These herbicides are commonly referred to by the nicknames of their chemical families, “FOPs,” “DIMs,” and “DENS.”

### **ALS Inhibitors (Branched-Chain Amino Acid Inhibitors) (Group 2)**

ALS inhibitors, or branched-chain amino acid inhibitors, comprise the largest mode of action and include at least one herbicide used in nearly every crop produced in Oklahoma. Many herbicides in this mode of action fall into two chemical families: imidazolinones (or “IMIs”) or sulfonyleureas (or “SUs”), but there are three other chemical families within the ALS inhibitors. Cross resistance, or herbicide-resistance to multiple chemical families within a single mode of action, is common with ALS inhibitors.

### **Root Growth Inhibitors (Group 3)**

Herbicides in this mode of action inhibit cell division, which stops roots from extending and are distinctive because of the yellow color of their formulations. They are applied preplant incorporated or preemergence in a wide range of agronomic crops, vegetables, turf, and ornamentals for control of grasses and small-seeded broadleaf weeds.

### **Growth Regulators (Group 4)**

This mode of action, also known as synthetic auxins, includes many commonly used plant hormone-type herbicides in wheat, corn, sorghum, and pasture settings. These herbicides are generally selective for broadleaf control in grass crops; however, there are some uses for preplant and in-season weed control in broadleaf crops.

### **Photosynthesis Inhibitors—Photosystem II (Groups 5, 6, and 7)**

These herbicides inhibit Photosystem II, part of the photosynthesis pathway, and are used in a variety of crops for control of grass and broadleaf weeds. Because of their extensive use for several decades, some weeds have developed resistance to these herbicides, particularly atrazine and metribuzin.

### **Shoot Growth Inhibitors (Groups 8 and 15)**

Herbicides in this mode of action are soil-applied herbicides and control weeds that have not emerged from the soil surface. These herbicides generally control grass weeds and small-seeded broadleaf weeds.

### **Aromatic Amino Acid Inhibitors (Group 9)**

The only herbicide included in this mode of action is glyphosate. There are many generic glyphosate and glyphosate-containing products available. Depending on the product, glyphosate can be formulated as ammonium, diammonium, dimethylammonium, isopropylamine, and/or potassium salts. Despite the different salt formulations available, it is important to know that the type of salt formulation does not affect weed control, but rather it indicates the way a particular glyphosate product is formulated. Glyphosate is a generally a non-selective herbicide and will severely injure or kill any living plant tissue that it comes in contact with. However, it can be used selectively in glyphosate-resistant crops, including corn, soybean, cotton, and canola. Like the ALS inhibitors, glyphosate controls susceptible plants by inhibiting amino acid synthesis; however, glyphosate and ALS inhibitors control susceptible plants in completely different ways and should not be considered to be the same mode of action.

### **Glutamine Synthesis Inhibitors (Group 10)**

The only herbicide included in this mode of action is glufosinate. Glufosinate can be used as a non-selective burndown treatment or as an over-the-top postemergence application in Liberty Link® crops (glufosinate resistant).

### **Pigment Synthesis Inhibitors (Groups 12, 13, 27)**

These herbicides are also called “bleachers” because of the characteristic white plant tissue that develops in susceptible plants after application. Several of the pigment synthesis inhibitors (mesotrione, isoxaflutole) are also referred to as HPPD-inhibitors, based on their site of action.

### **PPO Inhibitors (Groups 14)**

PPO inhibitors may also be referred to as cell membrane disruptors and are usually “burner”-type herbicides. Some PPO-inhibitors can be applied preemergence, but most are used for postemergence weed control.

### **Photosynthesis Inhibitors—Photosystem I (Group 22)**

Photosystem I inhibitors include paraquat and diquat and are used for non-selective weed control and crop desiccation prior to harvest. These herbicides are also referred to as “cell membrane disruptors” because of their contact activity.

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